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DEFENSE ACQUISITIONS

Improved Business Case Is Needed for Future Combat System's Successful Outcome

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Highlights

Highlights of GAO-06-367, a report to congressional committees

March 2006

DEFENSE ACQUISITIONS

Improved Business Case Is Needed for Future Combat System's Successful Outcome

Why GAO Did This Study

The Department of Defense (DOD) anticipates that the Future Combat System (FCS) will modernize the U.S. Army's ability to move, shoot, and communicate on the battlefield. It is an impressive concept that is the product of holistic, non-traditional thinking. The Army describes FCS as one of the most complex weapon acquisition programs ever executed because it involves developing and integrating a family of 18 systems and an information network. Army leadership started the program early as part of its effort to change Army culture and believes that the program risks are manageable.

GAO is required by law to review the program annually. In this report, GAO analyzes FCS's acquisition business case and assesses requirements stability, technology maturity, soundness of the acquisition strategy, and reasonableness and affordability of program costs.

What GAO Recommends

In order to improve the FCS's business case, GAO is making recommendations to the Secretary of Defense that involve setting clear expectations for progress and evaluating that progress by 2008. DOD partially concurred with our recommendations. This report also contains matters for congressional consideration to ensure FCS has a sound business case before future funding commitments are made.

www.gao.gov/cgi-bin/getrpt?GAO-06-367.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Paul L. Francis at (202) 512-4841 or francisp@gao.gov.

What GAO Found

The FCS entered the development phase in 2003 and has not yet reached the level of knowledge it should have attained in the pre-development stage. The elements of a sound business case—firm requirements, mature technologies, a knowledge-based acquisition strategy, a realistic cost estimate, and sufficient funding—are still not demonstrably present. The Army will continue building basic knowledge in areas such as requirements and technologies for several more years.

Requirements stability. The Army has reached agreement on FCS system of systems requirements—about 11,500—that help define how FCS units are expected to work as a whole. But the Army must continue to work out the technical feasibility and expected costs of the requirements for individual FCS systems. These requirements may not be completely stabilized until 2008. Until then, the Army expects the system-level requirements to change and to make trade-offs to offset technical risks and cost.

Technology maturity. None of FCS's 49 critical technologies was at a level of maturity recommended by DOD policy at the start of a program. Some technologies may not reach full maturity until after production starts. Not having firm requirements matched with mature technologies at the start of development is a key indicator of program risk. Also, the Army is depending on 52 complementary programs, each of which is essential for FCS to perform as intended. Some of these programs have significant technical challenges; some do not have the funding needed to complete development.

Soundness of acquisition strategy for design and production. The current acquisition strategy for FCS is improved over the original strategy but still calls for maturing technologies, designing systems, and preparing for production at the same time. Even if requirements and technologies proceed without incident, FCS design and production process maturity will not be demonstrated until after the production decision is made. Although production representative prototypes will not be available, the Army plans to test all FCS systems before committing to production. If problems are discovered in testing at that stage, they will be very expensive to correct.

Reasonableness and affordability of program costs. The estimated cost of the FCS program now stands at $160.7 billion, a 76 percent increase since program start. This is a better estimate than the original, as it embodies a more realistic schedule and scope. Including the total investment for the 52 essential complementary programs, the FCS program cost estimate would reach the $200 billion range. The Army has taken steps it believes will control FCS costs. Yet, the current level of knowledge about FCS is low, which makes it difficult to have a solid basis for cost projections. FCS's long-term affordability depends on the accuracy of cost estimates, an increased level of procurement funding, and the level of competing demands.

Contents

Figures

Abbreviations

DOD	Department of Defense
FCS	Future Combat System
JTRS	Joint Tactical Radio System
TRL	technology readiness level
WIN-T	Warfighter Information Network-Tactical

United States Government Accountability Office
Washington, DC 20548

March 14, 2006

Congressional Committees

The Department of the Army (Army) is in the midst of transforming itself into a lighter, more agile, and more capable combat force that will be better equipped to meet the defense challenges of the future. One of the centerpieces of the Army's transformation is the Future Combat System (FCS), a weapon systems acquisition program that embraces a new concept of operations, new technologies, and a new information network of numerous ground and air vehicles, sensors, and munitions. The Army itself calls this the "greatest technology and integration challenge the Army has ever undertaken." The FCS concept demonstrates the Army's desire to be proactive in preparing for the changing scope of modern warfare. When factoring in other Army programs needed to deliver FCS's full capability, the total investment costs are on the order of $200 billion. Spending of this magnitude has drawn attention in Congress because the nation is facing a large and growing deficit. Fiscal realities are putting pressure on the Army and the rest of the Department of Defense (DOD) to take a hard look at how it is managing its resources for weapon acquisition programs, such as FCS.

Given the Army's challenges to date and the cost and scope of the FCS program, the National Defense Authorization Act for Fiscal Year 2006 requires GAO to report annually on the product development phase of the FCS's acquisition. Congressional Committees and GAO agreed that this report should analyze FCS against the basic elements of an acquisition business case, namely: (1) firmness of requirements, (2) maturity of critical technologies, (3) soundness of the acquisition strategy as it relates to design and production, and (4) reasonableness and affordability of program costs.

In conducting our work, we have contacted numerous DOD and Army offices. We reviewed many documents pertaining to the FCS program, attended meetings at which DOD and Army officials reviewed program progress, and we held discussions with key DOD and Army officials on various aspects of the program. Officials from DOD and the Army have provided us access to sufficient information to make informed judgments on the matters in this report. In addition, we drew from our large body of past work on weapon systems acquisition practices. We reviewed DOD's acquisition policy, the experiences of successful and unsuccessful DOD programs, and the best acquisition practices of leading commercial firms.

We performed our work from June 2005 to March 2006 in accordance with generally accepted government auditing standards. Appendix I further discusses our scope and methodology.

Results in Brief

Today, about one-third of the way and $4.7 billion through FCS's development, the Army does not yet have the level of knowledge—such as firm requirements and mature technologies—it needed three years ago when it began product development. Army leadership started the program early as part of an overall effort to change the culture of the Army and believes that the risks in the program are manageable. While progress has been made and efforts are continuing in the requirements and technologies areas, the Army has not yet fulfilled the basic elements of a sound business case for a weapon system acquisition, including firm requirements, mature technologies, a sound strategy for attaining design and production maturity, realistic program cost estimates, and sufficient funding.

The Army has made significant progress defining the initial FCS system of systems requirements, having reached agreement on nearly 11,500. However, FCS requirements are not yet matched with program resources because the Army still faces the daunting task of defining about 90,000 more requirements for FCS's 18 individual systems. Although firm requirements should have been established at the start of the program, the process of setting and refining FCS system-level requirements may not be complete until 2008. The initial system-level requirements defined to date are likely to change as technical feasibility and expected costs of the system-level requirements become clearer. The Army plans to trade off system requirements to offset technical risks and cost, but this flexibility is not unlimited as FCS overall capabilities are still expected to be as good as or better than those of the current Army forces in terms of lethality, survivability, responsiveness, and sustainability.

None of the FCS's 49 critical technologies were at an acceptable level of maturity[1] when the product development began. Since the FCS program began, projected dates for maturing critical technologies have slipped, and some technologies are not expected to mature until very late—well into

[1] According to DOD policy, technology maturity means a technology must have been demonstrated in a relevant environment (or, preferably, in an operational environment) and considered mature enough to use for product development in systems integration.

the design phases of the program and possibly into production. Other challenges have arisen as well. Several of 52 complementary systems considered essential to FCS may not be able to complete development when needed. Some of these programs have not yet been fully funded, and others are facing their own technical challenges. For example, the Joint Tactical Radio System could be a deciding factor in FCS's overall success, but it is being restructured because of significant development problems.

The FCS acquisition strategy is not knowledge-based: the strategy calls for maturing technologies, designing systems, and preparing for production concurrently. Even if requirements definition and technology maturity proceed without incident, FCS design and production maturity will not be demonstrated under the current acquisition strategy until after the production decision is made. At this point, the critical design review is planned for the seventh year in a nine-year development, leaving little time to demonstrate the design will work as intended before the scheduled decision to begin production. In fact, the Army does not plan to build and test production-representative prototypes before committing to low-rate initial production. Design integration promises to be a major challenge, particularly for FCS's manned ground vehicles, which have been likened in sophistication to fighter aircraft. The late accumulation of design and production knowledge called for by the FCS acquisition strategy increases the likelihood that problems will be discovered in late development and early production, when the costs of fixes will be very high.

The low level of knowledge available today on requirements and technologies makes FCS cost projections very uncertain. Costs of the FCS program are estimated at $160.7 billion—an increase of 76 percent since the program began. The growth is attributable, in part, to the restructuring that increased the program's scope and extended the development schedule by four years. The projected costs also rose as program managers attained more knowledge about system of systems requirements. While the latest estimate may be better than earlier estimates, the essential complementary programs are not included. Including the costs of these programs would bring the required total investment to the $200 billion range. DOD has not yet prepared an independent estimate to validate the Army's current cost estimate. The Army is taking steps to control the costs of the program, but these steps may require changing or eliminating some requirements. The long-term affordability of FCS depends on the soundness of several key assumptions, including the accuracy of the cost estimate, the overall level of development and procurement funding available to the Army, and the level of competing demands.

We are making several recommendations to the Secretary of Defense to take a number of actions, prior to DOD's long-term commitment to the program, to improve the FCS business case and establish knowledge-based measures to guide oversight of FCS progress. DOD concurred with the intent of our recommendations; however, it did not agree to limit its commitment to the FCS program or to do much beyond what it had already planned to do. As a result, this report also contains matters for congressional consideration to ensure FCS has a sound business case before future funding commitments are made.

Background

The FCS concept is part of a pervasive change toward what the Army refers to as the Future Force. The Army is reorganizing its current forces into modular brigade combat teams, meaning troops can be deployed on different rotational cycles as a single team or as a cluster of teams. The Future Force is designed to transform the Army into a more rapidly deployable and responsive force and enables the Army to move away from the large division-centric structure of the past. Each FCS brigade combat team is expected to be highly survivable and the most lethal brigade-sized unit the Army has ever fielded. The Army expects FCS-equipped brigade combat teams to provide significant warfighting capabilities to DOD's overall joint military operations. The Army is implementing its transformation plans at a time when current U.S. ground forces are playing a critical role in the ongoing conflicts in Iraq and Afghanistan.

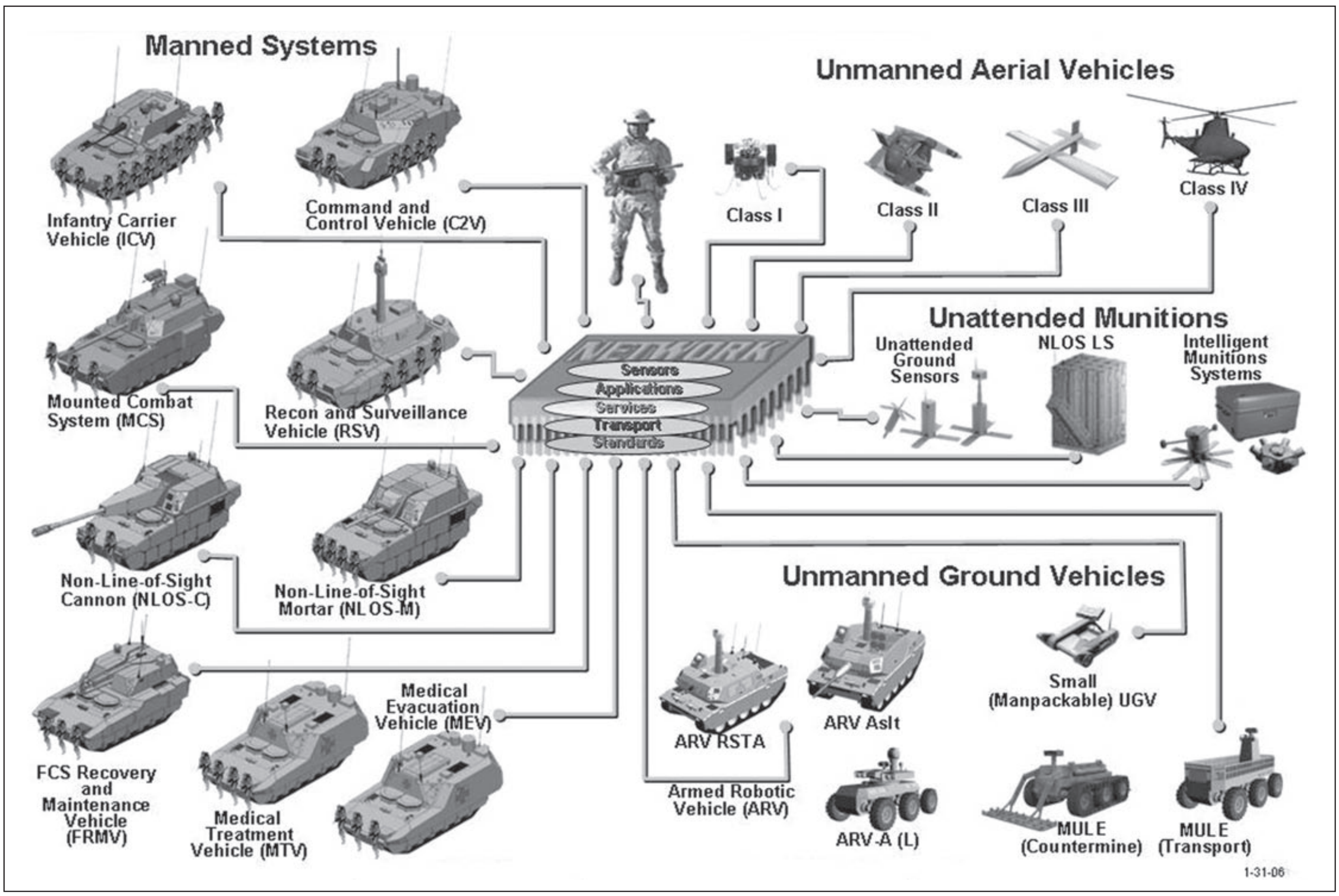
The FCS family of weapons includes 18 manned and unmanned ground vehicles, air vehicles, sensors, and munitions that will be linked by an information network. The systems include

- eight new types of manned ground vehicles to replace current tanks, infantry carriers, and self-propelled howitzers;
- four classes of unmanned aerial vehicles;
- several unmanned ground vehicles; and
- an attack missile.

At a fundamental level, the FCS concept is to replace mass with superior information—that is, to see and hit the enemy first rather than to rely on heavy armor to withstand a hit. This solution attempts to address the mismatch that has posed a dilemma to the Army for decades. The Army's heavy forces had the necessary firepower but required extensive support and too much time to deploy. Its light forces could deploy rapidly but lacked firepower. If the Future Force becomes a reality, then the Army would be better organized, staffed, equipped, and trained for prompt and

sustained land combat. This is expected to translate into a force that is responsive, technologically advanced, and versatile. These qualities are intended to ensure the Future Force's long-term dominance over evolving, sophisticated threats. The Future Force is to be offensively oriented and will employ revolutionary concepts of operations, enabled by new technology. The Army envisions a new way of fighting that depends on networking the force, which involves linking people, platforms, weapons, and sensors seamlessly together in a system of systems.

Figure 1: FCS's Core Systems



Source: U.S. Army.

If successful, the FCS system of systems concept will leverage individual capabilities of weapons and platforms and will facilitate interoperability and open system designs. This would be a significant improvement over the traditional approach of building superior individual weapons that must be retrofitted and netted together after the fact. This transformation, in terms of both operations and equipment, is under way with the full cooperation of the Army warfighter community. In fact, the development and acquisition of FCS is being accomplished using a uniquely collaborative relationship between the Army's developers, the participating contractors, and the warfighter community.

The Army has employed a management approach that centers on a lead systems integrator. Although there is no complete consensus on the definition of a lead systems integrator, those we are aware of appear to be prime contractors with increased program management responsibilities. These responsibilities have included greater involvement in requirements development, design, and source selection of major system and subsystem subcontractors. Boeing is the lead systems integrator for the FCS system development and demonstration phase of acquisition. The FCS lead systems integrator acts on behalf of the Army to optimize the FCS capability, maximize competition, ensure interoperability, and maintain commonality in order to reduce life cycle costs. The Army advised us that it did not believe it had the resources or flexibility to use its traditional acquisition process to field a program as complex as FCS under the aggressive timeline established by the then-Army Chief of Staff. The Army will maintain oversight and final approval of the lead systems integrator's subcontracting and competition plans.

FCS Restructures the Program and Changes Contracting Approach

As a key element of its efforts to transform itself, the Army has recognized FCS from its outset as the greatest technology and integration challenge it has ever undertaken. In May 2003, DOD approved the FCS program to begin the system development and demonstration phase, a milestone that ideally marks the completion of technology development and the start of product development. However, FCS's entry into this phase was premature given that the program had failed to satisfy basic tenets of DOD acquisition policy. We have reported that, as FCS started product development, it did not have mature technologies or adequately defined requirements.

Responding to direction from the Army Chief of Staff, the Army announced in July 2004 its plans to restructure the FCS program. The Army added four years to develop and mature the manned ground

vehicles, added more demonstrations and experiments, and established an evaluation unit to demonstrate FCS capabilities. The restructuring reintroduced four systems that previously had been left unfunded, raising the total number of FCS-related systems to 18. The restructure also included plans to spin off mature FCS capabilities as they become available to current force units. With the restructuring, the FCS program now plans to achieve initial operational capability in fiscal year 2015 and full operational capability in fiscal year 2017. FCS low-rate production is expected to start in fiscal year 2012, and full-rate production in fiscal year 2016. The Army intends to continue FCS procurement through fiscal year 2025, eventually equipping 15 brigade combat teams.

The restructuring was not the only major modification to the FCS program. Because of congressional concerns that the Army's contracting approach incorporated insufficient safeguards to protect the government's interests, the Army is preparing a new contract that is to be completed and finalized in March 2006 and is based on the Federal Acquisition Regulation, which governs acquisitions within the federal government. The new contract will incorporate standard Federal Acquisition Regulation clauses such as those relating to procurement integrity, Truth in Negotiations, and Cost Accounting Standards. Previously, the lead systems integrator had been performing FCS work for the Army under a contractual instrument called an "other transaction agreement" that was not subject to the Federal Acquisition Regulation. The other transaction agreement gave the Army considerable flexibility to negotiate the terms and conditions for contractors involved in FCS development. The Army's purpose for using such an agreement was to encourage innovation and to use its wide latitude in tailoring business, organizational, and technical relationships to achieve the program goals. In April 2005, the Army decided to incorporate into its agreement the procurement integrity, Truth in Negotiations, and Cost Accounting Standards clauses from the regulation.

After the Congress raised questions about the Army using an other transaction agreement for the development of a program as large and risky as FCS and about the Army's choice not to include standard Federal Acquisition Regulation clauses in the agreement, the Secretary of the Army directed that the other transaction agreement be converted to a Federal

Acquisition Regulation-based contract.[2] All of the work performed under the product development phase as of September 2005 will be accounted for under the prior other transaction agreement, and all work after September 2005 will be performed under the new contract. The Army expects the content of the program—its statement of work—will remain largely the same, and it does not expect the cost, schedule, and performance of the overall development effort to change materially.

Elements of a Business Case

We have frequently reported on the importance of using a solid, executable business case before committing resources to a new product development effort. In the case of DOD, a business case should be based on DOD acquisition policy and lessons learned from leading commercial firms and successful DOD programs. The business case in its simplest form is demonstrated evidence that (1) the warfighter's needs are valid and that they can best be met with the chosen concept, and (2) the chosen concept can be developed and produced within existing resources—that is, proven technologies, design knowledge, adequate funding, and adequate time to deliver the product when it is needed. A program should not go forward into product development unless a sound business case can be made. If the business case measures up, the organization commits to the development of the product, including making the financial investment.

At the heart of a business case is this knowledge-based approach to product development that is both a best practice among leading commercial firms and the approach preferred by DOD in its acquisition regulations. For a program to deliver a successful product within available resources, managers should demonstrate high levels of knowledge before significant commitments are made. In essence, knowledge supplants risk over time. This building of knowledge can be described as three levels or knowledge points that should be attained over the course of a program:

- First, at program start, the customer's needs should match the developer's available resources—mature technologies, time, and funding. An indication of this match is the demonstrated maturity of the technologies needed to meet customer needs. The ability of the

[2] In Section 212 of the Fiscal Year 2006 Defense Authorization Act, the Congress also stipulated that the Secretary of the Army procure the FCS through a Federal Acquisition Regulation contract.

government acquisition workforce to properly manage the effort should also be an important consideration at program start.

- Second, about midway through development, the product's design should be stable and demonstrate that it is capable of meeting performance requirements. The critical design review is the vehicle for making this determination and generally signifies the point at which the program is ready to start building production-representative prototypes.

- Third, by the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets and have demonstrated its reliability. It is also the point at which the design must demonstrate that it performs as needed through realistic system-level testing.

The three knowledge points are related in that a delay in attaining one delays the points that follow. Thus, if the technologies needed to meet requirements are not mature, design and production maturity will be delayed. On the successful commercial and defense programs we have reviewed, managers were careful to conduct development of technology separately from and ahead of the development of the product. For this reason, the first knowledge point is the most important for improving the chances of developing a weapon system within cost and schedule estimates. DOD's acquisition policy has adopted the knowledge-based approach to acquisitions. DOD policy requires program managers to provide knowledge about certain aspects of a system at key points in the acquisition process. Program managers are also required to reduce integration risk and demonstrate product design prior to the design readiness review and to reduce manufacturing risk and demonstrate producibility prior to full-rate production.

The FCS program is about one-third of the way into its scheduled product development. At this stage, it should have attained knowledge point one, with a strategy for attaining knowledge points two and three. Accordingly, we analyze the FCS business case first as it pertains to firming requirements and maturing technologies, which indicate progress against the first knowledge point. We then analyze FCS's strategy for attaining design and production maturity. Finally, we analyze the costs and funding estimates made to execute the FCS business case.

Army Has Made Progress but Feasibility and Affordability of System-level Requirements Remain Uncertain

The Army has made significant progress defining FCS's system of systems requirements, particularly when taking into account the daunting number of requirements involved—nearly 11,500—at this level. Yet system-level requirements are not yet stabilized and will continue to change, postponing the needed match between requirements and resources. Now, the Army and its contractors are working to complete the definition of system-level requirements, and the challenge is in determining if those requirements are technically feasible and affordable. Army officials say it is almost certain that some FCS system-level requirements will have to be modified, reduced, or eliminated; the only uncertainty is by how much. We have previously reported that unstable requirements can lead to cost, schedule, and performance shortfalls. Once the Army gains a better understanding of the technical feasibility and affordability of the system-level requirements, trade-offs between the developer and the warfighter will have to be made, and the ripple effect of such trade-offs on key program goals will have to be reassessed.

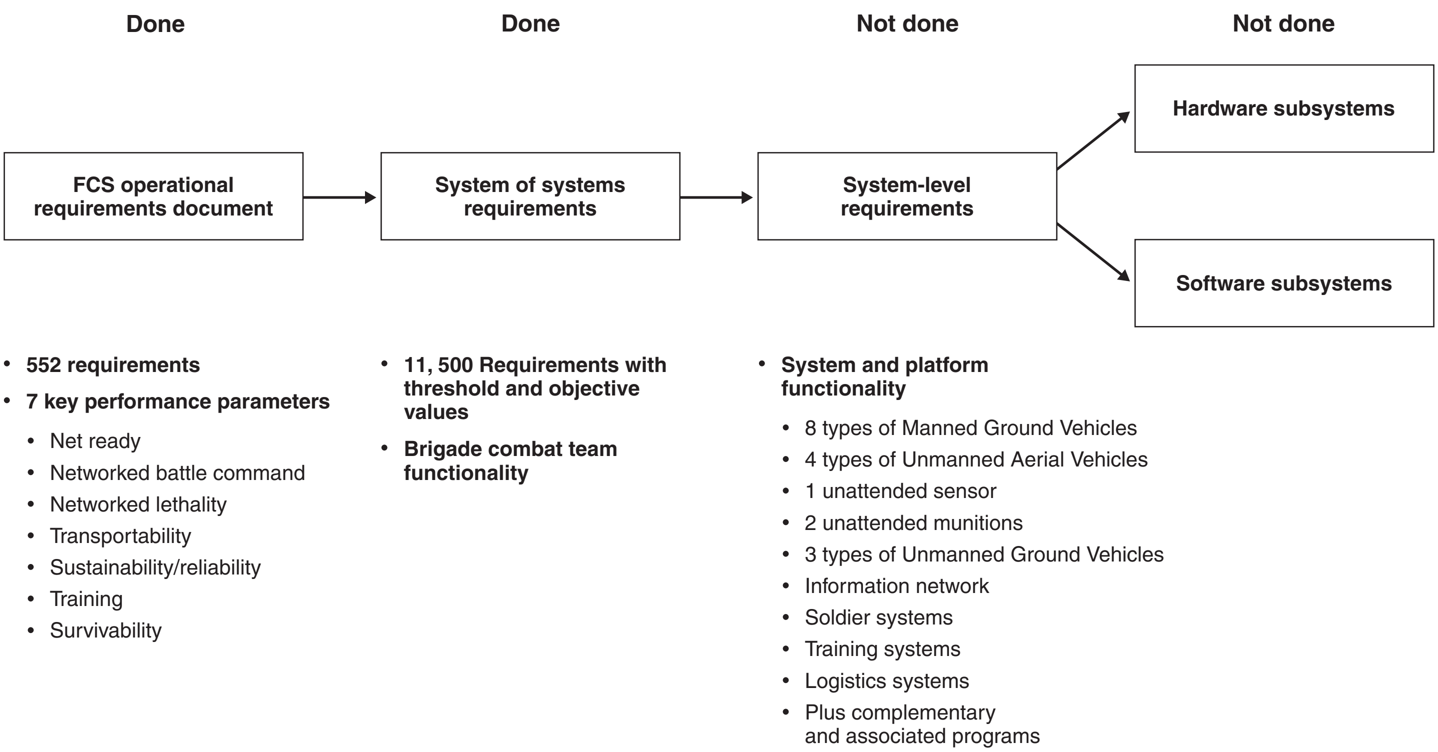
Army Has Largely Completed the Definition of FCS System of Systems Requirements

The Army has completed an FCS operational requirements document, a mandatory step in the DOD acquisition process. This document outlines 552 requirements intended to meet the warfighter's needs and discusses the characteristics needed for the FCS-equipped brigade combat teams to achieve the Army's desired tactical concepts and capabilities.[3] FCS is described in this document as a family of systems comprising advanced, networked air- and ground-based maneuver, maneuver support, and sustainment systems. The program has seven key performance parameters: network-ready, networked battle command, networked lethality, transportability, sustainability/reliability, training, and survivability. In simpler terms, the Army has stated that the FCS-equipped brigade combat teams must be as good as or better than current Army forces in terms of lethality, responsiveness, sustainability, and survivability. Since the FCS program started in May 2003, the Army and the lead systems integrator have been working to translate those warfighter requirements first into system of systems requirements at the FCS level. Having this information in hand gives the Army a good understanding of what FCS brigade combat teams should be capable of, but more detailed knowledge is needed for each of the 18 individual systems. Now, the Army

[3] The Army's concept for future warfighting is documented in *The United States Army Future Combat Force Operational and Organizational Plan for the Future Combat System Brigade Combat Team*. The FCS operational requirements document was derived from the operational and organizational plan.

and the lead systems integrator are delving much deeper and more precisely to translate system of systems requirements into more specific requirements for individual systems within FCS. Figure 2 illustrates how the requirements laid out in the operational requirements document flow down to the FCS's system of systems and later to the individual system level.

Figure 2: Flow of FCS's Overarching Requirements to System-level Requirements



Source: U.S. Army (data); GAO (analysis and presentation).

During the requirements definition process, the Army, its lead systems integrator, and other contractors provided feedback on the feasibility of the requirements being proposed. The feedback sometimes resulted in several rounds of negotiations and trade-offs before requirements could be finalized. For example, the Army has invested much time and effort in deciding how best to meet the FCS transportability requirements while continuing to meet its lethality and survivability requirements. A series of design concepts were used to examine the possibilities, and the Army and the lead systems integrator have conducted numerous design trade studies. Since program start, the Army has made a number of design trade-

offs that have been incorporated into the current design concepts. For example, the current manned ground vehicle design concepts feature a basic, lightly armored vehicle (each weighing about 19 tons) and additional armor (bringing the total vehicle weight up to about 24 tons). This trade-off was intended to achieve an acceptable level of survivability while maintaining a limited capability for the vehicles to be transported on the C-130 Hercules air lifter. The Army also decided to accept a higher weight to achieve the lethality of the 120-mm cannon for the mounted combat system. Finally, the Army decided to accept a reduction in range inherent in the lighter weight 38-caliber 155-mm cannon for the non-line-of-sight cannon vehicle.

In August 2005, the Army and the lead systems integrator conducted the System of Systems Functional Review, which is a multi-disciplined technical review used to ensure that a system can proceed into preliminary design. The review is conducted to ensure that all system of systems requirements have been defined and are consistent with program budget, schedule, risk, and other constraints. The Army and the lead systems integrator demonstrated that they had (1) essentially completed the definition of the system of systems level requirements, (2) established the functional baseline for the program, and (3) made an initial allocation of functional requirements down to the individual FCS system level. As shown in figure 2 above, at the system of systems level, there are about 11,500 requirements. The Army anticipates that there eventually could be eight times the number of requirements at the FCS system level, or roughly 90,000 requirements.

For the System of Systems Functional Review, the Army prepared a number of performance evaluations, including assessments of the entire brigade combat team's capabilities as well as more focused evaluations of individual FCS design concepts or requirements. The Army is conducting performance evaluations while continuing to evaluate requirement trade-offs and refine system-level requirements. These evaluations will be valuable in understanding the impact of individual requirement trade-off decisions on FCS capabilities as well as the Army's pledge that FCS would be as good as or better than the current Army forces in terms of lethality, survivability, responsiveness and sustainability.

FCS System-Level Requirements Are Not Yet Firm

The Army deserves credit for having decided on so many requirements at the system of systems level and for beginning the process allocating functional requirements to the individual system level. However, according to DOD policy and best practices, requirements should be

firmed up at the beginning of the product development phase. System requirements—how big, how heavy, how fast, how strong—can each be expressed in multiple ways. In deciding how best to address those system-level requirements, trade-offs may be necessary. Ideally, solutions go through a prioritization and refinement process before final decisions can be agreed upon. But continuing to define and refine system-level requirements three years after product development began creates a real challenge for the other elements of the FCS business case.

Signs of instability in FCS system-level requirements are already evident. At the System of Systems Functional Review, an initial assessment was made of the technical feasibility of the functional requirements allocated to the individual FCS systems. While many are expected to be achievable, there would be technical risk in the full achievement of some system-level requirements including

- mine detection;
- automatic target recognition for weapon terminal guidance;
- real-time battle damage assessment;
- chemical and radiation detection;
- weapon self-loading for some of the unmanned ground vehicles;
- manned ground vehicle countermine capabilities;
- safe operation of unmanned ground vehicles;
- network latency, quality of service, and intrusion detection;
- improvised explosive device detection and suppression;
- reliability, availability, maintainability, and testing;
- unmanned air vehicle size and weight;
- hidden target detection; and
- sensor data fusion.

The Army's System of Systems Functional Review also underscored how critical the FCS information network is to the achieving of many of FCS's requirements. For example, FCS survivability depends on the brigade-wide availability of network-based situational awareness plus the inherent survivability of the FCS platforms. There is hardly any aspect of FCS functionality that is not predicated on the network, and for many key functions, the network is essential. As we will discuss later in this report, there is considerable technical uncertainty surrounding several key aspects of the FCS network.

In the coming months, FCS teams working on individual systems will continue to evaluate the technical feasibility of addressing the allocated requirements within their current design concepts. Program officials also

will be conducting functional reviews at the system level. According to Army officials, it is almost certain that some of the FCS system-level requirements will have to be changed; it is only uncertain by how much. The Army does have the ability to reallocate a requirement from one system to another. The Army plans to evaluate its progress in defining and refining FCS system-level requirements at the August 2006 initial preliminary design review, which signals the start of the systems engineering process as well as the beginning of preliminary design work. However, the Army may not have a stabilized set of technically feasible and affordable system-level requirements until 2008.

Concurrently, the system-level teams will be evaluating the affordability of fully developing and producing each of the FCS systems and platforms to meet the allocated requirements. The Army has stated it will not exceed the target cost of $20.9 billion for the lead systems integrator's development contract and will attempt to produce the FCS systems and platforms within specific procurement cost targets. Key FCS program officials have indicated to us that additional system-level requirements changes will be needed to meet these targets.

Applying the discipline of affordability is a good step, but it can make the requirement definition process more difficult. For example, to meet the weight goals for the manned ground vehicles, the Army expects to use advanced, light weight materials, such as ceramics, rather than traditional steel for armor protection. However, these materials are expected to be much more costly to produce than steel. To meet the individual manned ground vehicle's survivability requirements, each vehicle will have to be equipped for detection avoidance, target acquisition avoidance, hit avoidance, ballistic protection, and kill avoidance. Further, each manned ground vehicle would have to carry sensors that can detect, classify, recognize, identify, and locate enemy combatants. All of these capabilities will add to the cost of developing and producing the manned ground vehicles. Finally, the FCS concept depends, among other things, on the capabilities of the unmanned ground vehicles and unmanned air vehicles to enhance the survivability of the rest of the brigade combat team. However, a high number of unmanned ground vehicles and unmanned air vehicles themselves are expected to be lost to enemy fire. In the end, the Army may have to either provide additional unmanned ground vehicles and/or unmanned air vehicles or risk the loss of even more valuable manned ground vehicles and soldiers. Either option would involve additional costs.

Cumulative Effects of Individual Requirement Trade-Offs Must Be Measured

Since the start of the program, the Army has already made some requirements trade-offs. The Army realizes that the ripple effects of requirements trade-offs on the anticipated FCS capabilities will need to be thoroughly assessed to determine if the fundamental tenets of the program—such as being as lethal and survivable as the current Army force—are still intact. For example, in deciding to maintain a requirement for the manned ground vehicles to be transportable on C-130 aircraft, the Army determined that the vehicles could still meet their survivability and lethality requirements while meeting the size and weight restrictions needed to be compatible with the C-130 operating limitations. This solution involves, in part, the use of additional armor that would be put on the vehicle after it had been flown by a C-130 to its new operating location. The Army made this decision with the knowledge that the C-130 aircraft's capability to transport the FCS vehicles would be very limited and that the solution would require more C-130s to transport vehicles than previously planned. Also, as we pointed out in our March 2005 testimony, the development and integration of manned ground vehicle technologies was made vastly more difficult by the Army's decision to retain the C-130 transportability requirement. As the FCS development effort proceeds, the Army will have to regularly assess whether the manned ground vehicles will still be able to meet their lethality, survivability, and other requirements as well as the assumed operational value of maintaining the C-130 transportability requirement. Decision makers need to be kept informed on the status of the program's basic tenets, such as FCS capabilities being as good as or better than those of current Army forces.

As the technical feasibility and affordability of requirements are better understood, additional FCS requirements trade-offs will have to be made and their ripple effects identified. For example, if the requirements for FCS missile and munition terminal guidance are changed due to feasibility or cost issues, that may not have an impact only on lethality, but also on overall FCS survivability because the Army maintains that FCS survivability will be enhanced if it is able to see first and kill first. Also, if the FCS weapon terminal guidance requirements are changed, the brigade combat teams may have to carry and use more weapons than expected, which would have an impact on the team's sustainability. As another example, if the FCS countermine requirements are changed, then FCS manned ground vehicles may be less survivable and mobile. The Army may have to add additional armor to the manned ground vehicles, directly affecting their weight and impacting their transportability and sustainability. Finally, if the reliability, availability, maintainability, and testing requirements are adjusted, the brigade combat teams may have to

carry more spare parts and use more maintenance personnel than originally anticipated.

The Army is aiming to field FCS systems and platforms that meet all of its minimally acceptable threshold requirements, but according to program officials, that may not be possible for all requirements. Further, it is unclear at this point if the resulting set of system-level requirements will yield an overall FCS capability that will be acceptable to the Army as a whole and its user representative, the Training and Doctrine Command. The Training and Doctrine Command has had extensive involvement in the program to date and would have to approve any major changes in FCS requirements. At the System of Systems Functional Review, the Training and Doctrine Command representatives pledged their continuing cooperation in the process but also vowed to appeal to the Army leadership if the FCS design concepts do not provide sufficient capabilities to meet their wartime needs.

FCS Success Hinges on Numerous Undemonstrated Technologies and Complementary Programs

According to the latest independent assessment,[4] the Army has not fully matured any of the technologies critical to FCS's success. Some of FCS's critical technologies may not reach a high level of maturity until the final major phase of acquisition, the start of production. The Army considers a lower level of demonstration as acceptable maturity, but even against this standard, only one-third of the technologies are mature. We have reported that proceeding into product development without demonstrating mature technologies increases the risk of cost growth and schedule delays throughout the life of the program. The Army is also facing challenges with several of the complementary programs considered essential for meeting FCS's requirements. Some complementary programs are experiencing technology difficulties, and some have not been fully funded. These difficulties underscore the gap between requirements and available resources that must be closed if the FCS business case is to be executable.

Critical Technologies Are a Long Way from Reaching Maturity

Technology readiness levels (TRL) are measures pioneered by the National Aeronautics and Space Administration and adopted by DOD to determine whether technologies were sufficiently mature to be incorporated into a weapon system. Our prior work has found TRLs to be

[4] *Technology Readiness Assessment Update*, Office of the Deputy Assistant Secretary of the Army for Research and Technology, April 2005.

a valuable decision-making tool because they can presage the likely consequences of incorporating a technology at a given level of maturity into a product development. The maturity level of a technology can range from paper studies (level 1), to prototypes that can be tested in a realistic environment (level 7), to an actual system that has proven itself in mission operations (level 9). The definitions of each TRL can be found in appendix IV. According to DOD acquisition policy, a technology should have been demonstrated in a relevant environment (TRL 6) or, preferably, in an operational environment (TRL 7) to be considered mature enough to use for product development in systems integration. Best practices of leading commercial firms and successful DOD programs have shown that critical technologies should be mature to at least a TRL 7 before the start of product development.

In the case of the FCS program, the latest independent technology assessment shows that none of the critical technologies are at TRL 7, and only 18 of the 49 technologies currently rated have demonstrated TRL 6. None of the critical technologies may reach TRL 7 until the production decision in fiscal year 2012, according to Army officials. Five technologies that the Army previously considered to be critical to FCS are no longer being monitored for technology maturity, although those technologies continue to be under development by either the Army or another military service. Table 1 sorts FCS's critical technologies according to readiness levels, and their progression over the last two years.

Table 1: Number of FCS Critical Technologies Sorted by TRLs

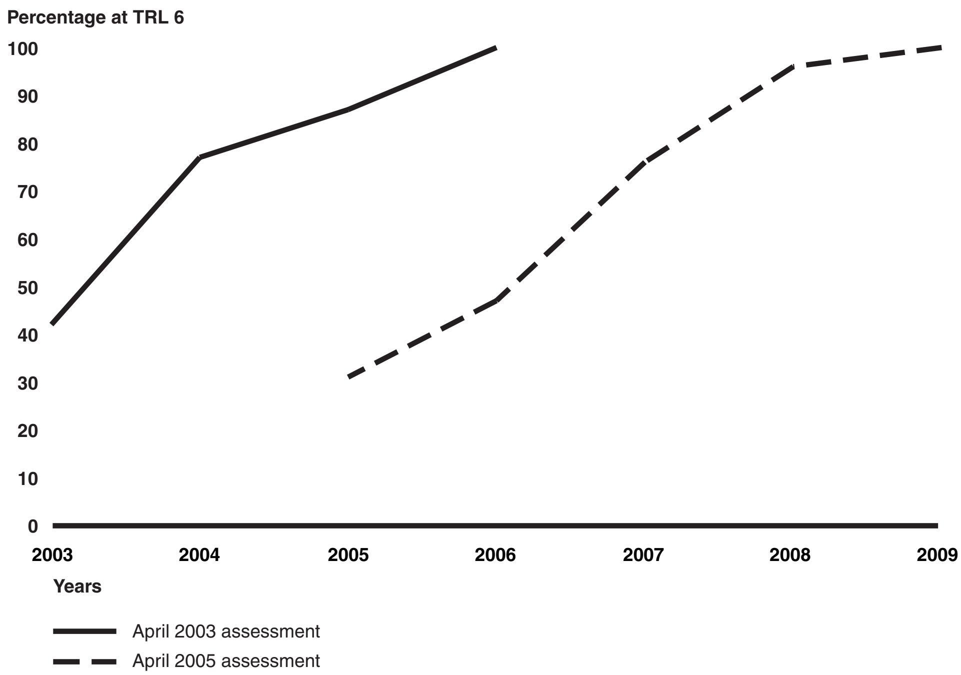
TRL	Critical technology assessment as of April 2003	Critical technology assessment as of April 2005
TRL 7 and higher	1	0
TRL 6	7	18
TRL 5 and lower	24	31
Total	**32**	**49**

Source: U.S. Army (data); GAO (analysis and presentation)

Note: The April 2003 assessment was organized into 31 technology areas, one of which had two different TRL ratings for separate technologies. For the April 2005 assessment, the original 31 technology areas were subdivided into 54 individual technologies. Five of the original technologies are no longer being tracked, leaving a total of 49.

Projected dates for FCS technologies to reach TRL 6 have slipped significantly since the start of the program, as shown in figure 3.

Figure 3: Comparison of Projected Dates for Technology Maturity



Source: U.S. Army (data); GAO (analysis and presentation).

In the 2003 technology assessment, 87 percent of FCS's critical technologies were projected to be mature to a TRL 6 by 2005. In April 2005, 31 percent of the technologies were expected to mature to a TRL 6 by 2005, and all technologies are not expected to be mature to that level until 2009. Several key technologies have slipped. For example, to meet FCS survivability and sustainability requirements, the Army requires High Density Packaged Power, a technology designed to provide high-output, constant-level, stored power to the FCS manned ground vehicles. This technology was originally projected to reach TRL 6 maturity by fiscal year 2003. In the latest assessment, however, that date slipped nearly five years to fiscal year 2008. Another technology, Quality of Service Algorithms, which are protocols implemented in network software and used to determine how information is moved and tracked to users, was originally expected to reach TRL 6 by fiscal year 2004, but now projected maturity has slipped three years. The Army originally anticipated the Lightweight Hull and Vehicle Armor to reach TRL 6 by fiscal year 2003; however, this has been delayed by five years. Appendix III lists all 54 critical technologies, their current TRL status, and the projected date for reaching TRL 6.

Technology and Integration Challenges for Manned Ground Vehicles

FCS features eight types of manned ground vehicles, each requiring the development of numerous technologies that must be brought together in an integrated design to deliver required capabilities. The Mounted Combat System will require a newly developed lightweight weapon for lethality; a hybrid electric drive system and a high-density engine for mobility; advanced armors, an active protection system, and advanced signature management systems for survivability; and the Joint Tactical Radio System with the wideband networking waveform for communications and network connectivity. FCS manned ground vehicles are expected to be revolutionary, not only because of their proposed capabilities but also in terms of their size and weight. They have been likened in complexity to fighter aircraft. Under other circumstances, each of the eight manned ground systems would be a major defense acquisition program in its own right.

Since 2003, the Army has been working to develop a series of design concepts and is currently evaluating the technical feasibility and affordability of the system-level requirements that have been allocated to each of the eight vehicles. By August 2006, the Army expects to decide which of those requirements will be pursued in the preliminary design, and which ones will have to be changed or deleted. Among many others, the achievement of the following manned ground vehicles requirements have been identified as involving technical and design challenges:

- engine,
- silent watch (which relates to battery capacity),
- 14.5-mm survivability,
- signature management,
- lightweight track, and
- power distribution.

As we noted earlier, several critical technologies are not projected to mature to a TRL 6 until fiscal year 2008 or 2009, at or around the point when the program should be starting detailed designs for each vehicle. Further, it should be noted that the step to mature technologies from a TRL 6 to a TRL 7 is often difficult and unpredictable. All told, the Army is unlikely to be able to match requirements with technical and design solutions until at least fiscal year 2008.

In addition, manned ground vehicles face several technology and integration challenges.

- The Active Protection System is expected to protect manned ground vehicles by sensing and destroying such threats as incoming tank rounds and rocket-propelled grenades. However, technology assessments have recognized that (1) it may not be possible to have a single, integrated active protection system that protects against all threats, (2) the Threat Warning System, a technology used to detect and track incoming threats at extended ranges, will not be mature to TRL 6 until fiscal 2009, (3) the part of the system to defeat kinetic energy threats will require significant effort from the science and technology community,[5] and (4) protection technology may have limited utility in urban environments due to collateral effects.

- The Army is considering integrating an electromagnetic armor as a defense layer for manned ground vehicles. However, electromagnetic armor is still an immature technology and poses integration issues, including requiring a large amount of power storage capability that may not be possible within vehicle design and weight constraints. Component maturation and size reduction will be needed to keep electromagnetic armor as a viable survivability approach.

- The integration of the 120-mm cannon on the Mounted Combat System vehicle poses design challenges. While the lightweight 120-mm cannon has achieved TRL 6 maturity that meets baseline requirements for the gun, this testing was conducted on a stationary hardstand and not on a turret or vehicle prototype. Those tests are planned for fiscal years 2007 and 2009, respectively. Realistic testing is important because program officials cannot be certain whether the turret and vehicle design will be able to withstand the gun blast without damage to the vehicle.

- The integration of the Lightweight Hull and Vehicle Armor in manned ground vehicles may also prove to be difficult, and there is a risk that the proposed lightweight armor will not satisfy transportability requirements while providing adequate protection. The design and integration issues must be addressed by large-scale ballistic testing, particularly for the cutting-edge ceramic armors being considered.

[5] Defeating kinetic energy threats is an objective, not a threshold, FCS requirement.

- Mine protection technology, intended to protect manned ground vehicles and occupants from mine blast, is still immature and has significant challenges that include blast armor development, armor repair, and structural and weight integration. Because of its immature status, the program is considering alternatives for its development.

The acceptable resolution of at least some of these issues—such as those involving the active protection system, lightweight hull and armor, and mine protection—may be important enough that they represent "go/no go" markers in the development of manned ground vehicles. For example, if the active protection system technology and integration issues cannot be acceptably resolved and its capabilities may be less than needed, it is unclear if the FCS program will be able to complete the detailed designs of the manned ground vehicles and meet the expectations for critical design review.

To meet the program's goal to have manned ground vehicle prototypes available in late fiscal year 2010 or early fiscal year 2011, their fabrication would probably have to start well before design stability is achieved. If technology and integration issues identified to date are not resolved by that point, it is questionable whether the level of system integration that may be available for the prototype designs and if their demonstration will be able to yield acceptable results.

Many Complementary Programs Are at Risk

The FCS program may have to interoperate or integrate with as many as 170 programs, some of which are in development and many are currently fielded programs. Many complementary programs are not being developed exclusively for FCS and are outside the direct control of the FCS program. Because of the complementary programs' importance to FCS, the Army closely monitors how well those efforts will synchronize with the FCS program. Of all the complementary programs, 52 are considered essential to meeting FCS key performance parameters. However, many of these programs have technical or funding problems and generally have uncertain futures.

FCS Information Network Depends on Complementary Programs

We reported in June 2005 that two key systems of the FCS network, the Joint Tactical Radio System (JTRS) and Warfighter Information Network-Tactical (WIN-T), were struggling to meet ambitious user requirements, steep technical challenges, and aggressive schedules, which raised uncertainty about the ability of the FCS network to perform as intended

and threatened the schedule for fielding Future Force capabilities.[6] We recommended that the Secretary of Defense establish low-risk schedules for JTRS and WIN-T and synchronize the FCS schedule with a demonstration of JTRS and WIN-T capabilities. DOD generally concurred and indicated it has begun taking action to address our recommendations. Since our report, JTRS has been undergoing a major restructuring to reduce technical and programmatic risks. In addition, WIN-T is being rebaselined to address the Army's recent shift in focus to meet both near- and future-term requirements, as well as to better synchronize with FCS. The results of the JTRS and WIN-T program restructurings are not expected to be completed and approved until later this year, however; preliminary indications are that the programs will focus on delivering incremental capabilities to support the needs of FCS and other users.

JTRS

JTRS is a family of software-based radios that is to provide the high capacity, high-speed information link to vehicles, weapons, aircraft, and soldiers. The JTRS program to develop radios for ground vehicles and helicopters—referred to as Cluster 1—began product development in June 2002 with an aggressive schedule, immature technologies, and lack of clearly defined and stable requirements. The Army has not been able to mature the technologies needed to provide radios that both generate sufficient power as well as meet platform size and weight constraints. In addition, the radio design is not sufficient to meet security requirements for operating in an open network environment. These factors have contributed to significant cost and schedule problems. In early 2005, the Office of the Secretary of Defense directed the Army to stop work on portions of the Cluster 1 development and have a newly established JTRS Joint Program Executive Office[7] conduct an assessment of the program and develop options for restructuring the program.

A second JTRS program—referred to as Cluster 5—to develop different variants of small radios that will be carried by soldiers and be embedded in several FCS core systems, also entered product development with immature technologies and a lack of well-defined requirements. Since the

[6] GAO, *Defense Acquisitions: Resolving Development Risks in the Army's Networked Communications Capabilities is Key to Fielding Future Force*. GAO-05-669. (Washington, D.C.: June 15, 2005).

[7] Joint Program Executive Office was established in February 2005 in response to the fiscal year 2004 National Defense Authorization Act which directed DOD to strengthen the joint management of all the JTRS program components.

program began in 2004, it has faced significant technical challenges due to the small size, weight, power, and large data processing requirements for the radios. As a result, the Army recognized in 2005 that the Cluster 5 program was not sufficiently synchronized with the FCS program and it began assessing the feasibility of accelerating the development of some of the small form Cluster 5 radios. However, in light of the problems encountered with the Cluster 1 program, DOD directed the JTRS Joint Program Executive Office to conduct a broad assessment of all the JTRS components and identify more well defined and executable increments for Cluster 5.

In December 2005, DOD approved a preliminary plan for restructuring the JTRS program, including Clusters 1 and 5. Details of the restructuring, however, are still to be worked out and the new program is not expected to be formally approved by DOD until late 2006. According to JTRS Joint Program Executive Office officials, the proposed program will address many of the concerns we raised in our July 2005 report and be structured to deliver capabilities in increments rather than all at once. The first increment is intended to support the FCS schedule. However, there are still cost, schedule, and technical risks associated with the planned delivery of increment one capabilities, and therefore it is unclear whether the capabilities will be available in time for the first spin-out of FCS capabilities to current forces in 2008.

WIN-T

The WIN-T program is intended to provide an integrated communications network to connect Army units on the move with higher levels of command and provide the Army's tactical extension to the Global Information Grid, a separate, DOD-wide networked force. The WIN-T program began with an aggressive acquisition schedule and entered product development with only three of its 12 critical technologies close to full maturity. The program office expects that all 12 critical technologies demonstrated during a November 2005 developmental test/operational test event will be assessed as close to fully mature. In August 2005, the Department of the Army conducted a study which explored options for better synchronizing three of its major system development efforts—FCS, JTRS, and WIN-T. As a result of this study, the WIN-T program will be rebaselined to meet emerging requirements. A new WIN-T capability development document will support the rebaselining of the program and is currently under review. A milestone B reexamination to rebaseline the program is planned for July 2006, and a new date for the WIN-T production decision will be established then.

The restructuring of the JTRS and WIN-T programs and the success in developing these capabilities could well be deciding factors in the overall success of the FCS program. If JTRS and WIN-T do not work as intended, there will not be sufficient battlefield information for the FCS units to operate effectively. Because the network is so crucial to the overall success of FCS, we have suggested that its development and demonstration should precede major commitments to other elements of the FCS program, particularly the manned ground vehicles. However, the Army has admitted that the development of the network is several years behind the development of other elements of the FCS program.

Funding Issues Cloud Future of Other Complementary Programs

The future of other complementary programs is in doubt primarily because of funding issues. The Compact Kinetic Energy Missile was to provide superior lethality against current tanks, bunkers, buildings, and future threat armor. The Joint Common Missile was to provide line-of-sight and beyond-line-of-sight capabilities and could be employed in a fire-and-forget mode or a precision attack mode. The Army has not yet decided if it will fund the full development of the Compact Kinetic Energy Missile. In December 2004, a DOD program budget decision deleted all procurement funding for the Joint Common Missile.[8] The absence of these systems could reduce the brigade combat teams' ability to fight at stand off ranges, thereby reducing lethality and the ability to dictate the terms of the engagement. The Mid-Range Munition is to provide beyond-line-of-sight precision munitions for the mounted combat system, but its development is unfunded after fiscal year 2007. Elimination of the Mid-Range Munition would compromise the beyond-line-of-sight capability—which is a FCS threshold operational requirement—as well as the Army's ability to shape the battle space and dictate the terms of the engagement. The Precision Guidance Kit is a technology for projectiles that provides greater accuracy at extended ranges, but the development of this technology is partially unfunded. If this technology is not available for FCS, then long-range projectiles would be less accurate, reducing their effectiveness and requiring additional rounds to be fired at the threat. As a result, the brigade combat team may need to carry additional munitions, an outcome that imposes a logistical and transportability burden. The Army also concedes that there is no funding to develop the following munitions needed to meet selected requirements: Advanced Kinetic Energy munition,

[8] In the fiscal year 2006 defense appropriation act, H.Report 109-359, page 372, Congress provided some funding to continue development of the Joint Common Missile.

Advance Multi-Purpose Munition, Javelin Block II missile, Loitering Attack Missile, and non-lethal munitions.

Recognizing the multiple issues surrounding complementary programs, the Army is reassessing its list of 52 essential programs. When that list is finalized in the coming months, the Army will have to determine how to replace any capabilities eliminated from the list. As with requirements, the cumulative effects of changes in technologies and complementary programs on overall FCS capabilities are important to measure. The Army's inability to fund all essential complementary programs raises concerns about the gap between requirements and resources.

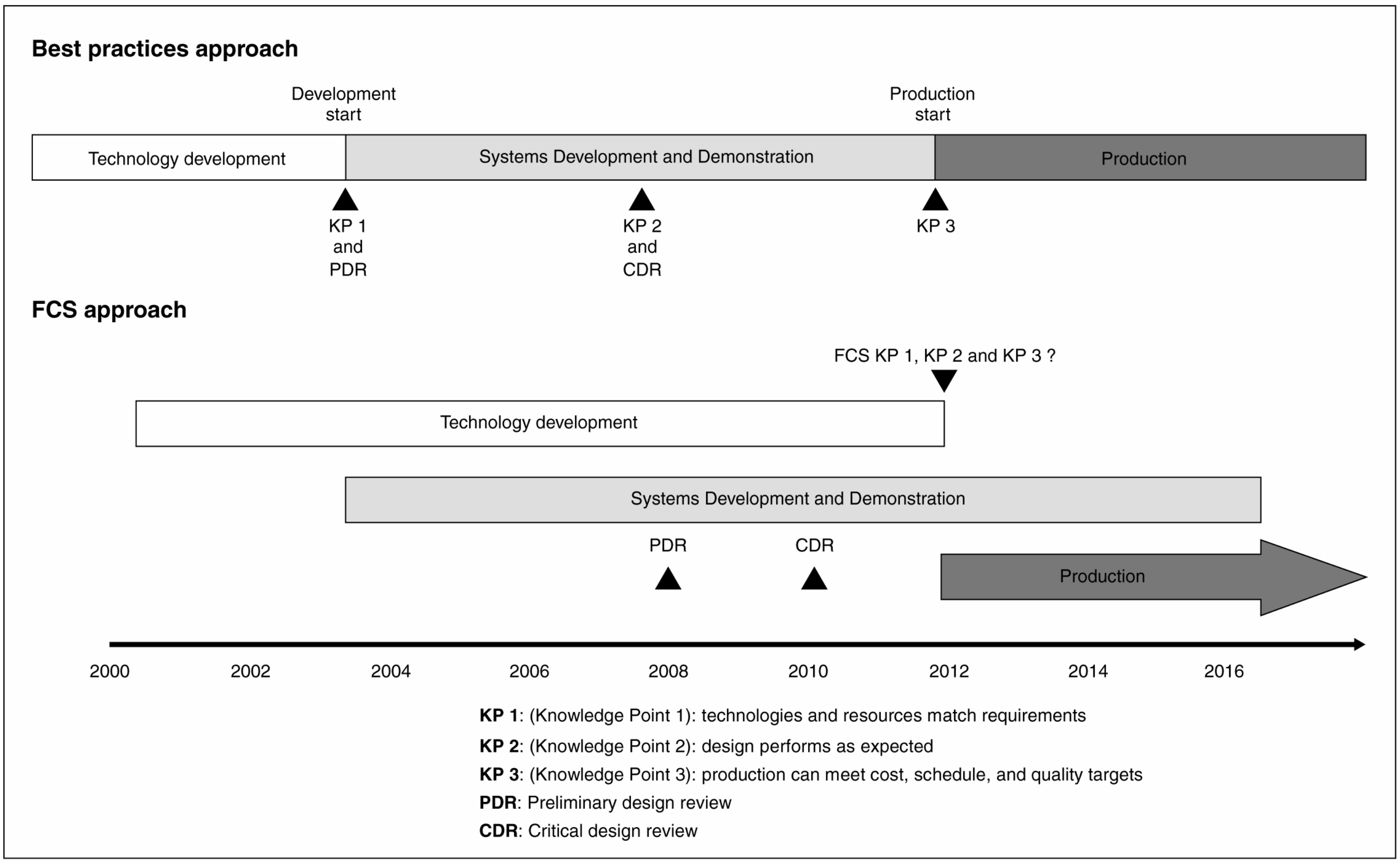
FCS Acquisition Strategy Will Demonstrate Design Maturity After Production Begins

The knowledge deficits for requirements and technologies have created enormous challenges for devising an acquisition strategy that can demonstrate the maturity of design and production processes. Even if requirements setting and technology maturity proceed without incident, FCS design and production maturity will still not be demonstrated until after the production decision is made. Production is the most expensive phase in which to resolve design or other problems. Several efforts within the FCS program are facing significant problems that may eventually involve reductions in promised capabilities and may lead to cost overruns and schedule delays.

FCS Acquisition Strategy Involves Concurrent Development and Is Not Knowledge-Based

The Army's acquisition strategy for FCS does not reflect a knowledge-based approach. Figure 4 shows how the Army's strategy for acquiring FCS involves concurrent development, design reviews that occur late, and other issues that are out of alignment with the knowledge-based approach outlined in DOD policy.

Figure 4: FCS Acquisition Compared with Commercial Best Practices' Approach



Source: Army (data); GAO (analysis and presentation).

Ideally, the preliminary design review occurs at or near the start of product development. Activities leading up to the preliminary design review include, among others, translating system requirements into design specifics. Doing so can help reveal key technical and engineering challenges and can help determine if a mismatch exists between what the customer wants and what the product developer can deliver. Scheduling the preliminary design review early in product development is intended to

help stabilize cost, schedule, and performance expectations. The critical design review ideally occurs midway into the product development phase. The critical design review should confirm that the system design performs as expected and is stable enough to build production-representative prototypes for testing. The building of production-representative prototypes helps decision makers confirm that the system can be produced and manufactured within cost, schedule, and quality targets. According to the knowledge-based approach, a high percentage of design drawings should be completed and released to manufacturing at critical design review. The period leading up to critical design review is referred to as system integration, when individual components of a system are brought together, and the period after the review is called system demonstration, when the system as a whole demonstrates its reliability as well as its ability to work in the intended environment.

The Army has scheduled the preliminary design review in fiscal year 2008, about five years after the start of product development. The critical design review is scheduled in fiscal year 2010, just two years after the scheduled preliminary design review and the planned start of detailed design.[9] This is not to suggest that the two design reviews for the FCS could have been scheduled earlier but rather that commitments to production are scheduled too soon afterward. The timing of the design reviews is indicative of how late knowledge will be attained in the program, assuming all goes according to plan. The critical design review is scheduled just two years before the initial FCS production decision in fiscal year 2012, leaving little time for product demonstration and correction of any issues that are identified at that time. The Army is planning to have prototypes of all FCS systems available for testing prior to low-rate initial production. For example, manned ground vehicle prototypes are expected to be available in late 2010 and early 2011 for developmental and qualification testing. However, these prototypes are not expected to be production-representative prototypes and may not be fully integrated. Whereas the testing of fully integrated, production-representative prototypes demonstrate design maturity and their fabrication can demonstrate production process maturity, neither of these knowledge points will be attained until after the production decision is made.

[9] The 2008 preliminary design review and the 2010 critical design review are culminating events; system-level preliminary design reviews and critical design reviews will be conducted prior to those dates.

The FCS program is thus susceptible to late-cycle churn, a condition that we reported on in 2000.[10] Late cycle churn is a phrase private industry has used to describe the efforts to fix a significant problem that is discovered late in a product's development. Churn refers to the additional—and unanticipated—time, money, and effort that must be invested to overcome problems discovered through testing. Problems are most serious when they delay product delivery, increase product cost, or "escape" to the customer. The discovery of problems in testing conducted late in development is a fairly common occurrence on DOD programs, as is the attendant late cycle churn. Often, tests of a full system, such as launching a missile or flying an aircraft, become the vehicles for discovering problems that could have been found out earlier and corrected less expensively. When significant problems are revealed late in a weapon system's development, the reaction—or churn—can take several forms: extending schedules to increase the investment in more prototypes and testing, terminating the program, or redesigning and modifying weapons that have already made it to the field. While DOD has found it acceptable to accommodate such problems over the years, this will be a difficult proposition for the FCS given the magnitude of its cost in an increasingly competitive environment for investment funds.

The Army is proceeding with its plans to mitigate FCS risks using modeling, simulation, emulation, and system integration laboratories. This approach is a necessary aspect of the Army acquisition strategy and is designed to reduce the dependence on late testing to gain valuable insights about many aspects of FCS development, including design progress. However, on a first-of-a-kind system—like FCS—that represents a radical departure from current systems and warfighting concepts, actual testing of all the components integrated together is the final proof that the FCS system of systems concept works both as predicted and as needed.

[10]GAO, *Best Practices: A More Constructive Approach is Key to Better Weapon System Outcomes*, GAO/NSIAD-00-199 (Washington, D.C.: July 31, 2000).

As FCS's Higher Costs Are Recognized, Funding Availability Becomes a Greater Challenge

The total cost for the FCS program, now estimated at $160.7 billion (then-year dollars), has climbed 76 percent from the Army's first estimate. Because uncertainties remain regarding FCS's system-level requirements and the Army faces significant challenges in technology and design maturity, we believe the Army's latest cost estimate still lacks a firm knowledge base. Furthermore, this latest estimate does not include complementary programs that are essential for FCS to perform as intended, or the necessary funding for spin-outs. The Army has taken some steps to help manage the growing cost of FCS, including establishing cost ceilings or targets for development and production. However, program officials told us that setting cost limits may result in accepting lower capabilities. As FCS's higher costs are recognized, it remains unclear whether the Army will have the ability to fully fund the planned annual procurement costs for the FCS current program of record. FCS affordability depends on the accuracy of the cost estimate, the overall level of development and procurement funding available to the Army, and the level of competing demands.

FCS Costs Have Increased as Army Attains More Information, but Firm Knowledge Base Still Lacking

At the start of product development, FCS program officials estimated that the program would require about $20 billion in then-year dollars for research, development, testing, and evaluation and about $72 billion to procure the FCS systems to equip 15 brigade combat teams. At that time, program officials could only derive the cost estimate on the basis of what they knew then—requirements were still undefined and technologies were immature. The total FCS program is now expected to cost $160.7 billion in then-year dollars, a 76 percent increase. Table 2 summarizes the growth of the FCS cost estimate.

Table 2: Comparison of Original Cost Estimate and Current Cost Estimate for FCS Program (in billions of then-year dollars)

	Original estimate	Revised estimate (as of 1/2006)	Percentage increase
Research, development, testing, and evaluation	$19.6	$30.5	56%
Procurement	$71.8	$130.2	81%
Total	$91.4	$160.7	76%

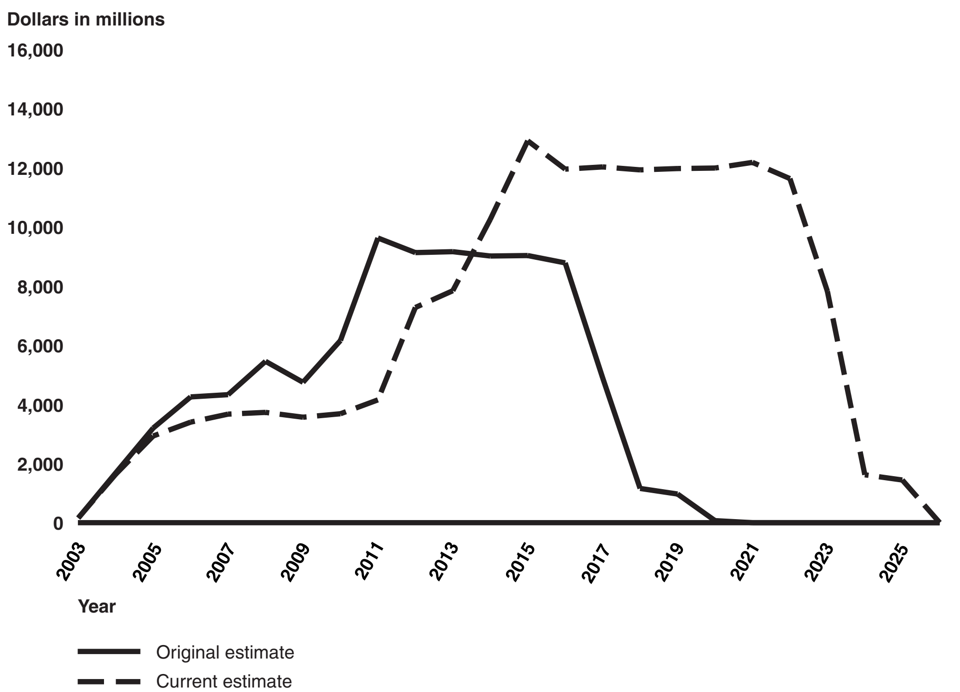
Source: Army (data); GAO (analysis and presentation).

According to the Army, the current cost estimate is more realistic, better informed, and based on a more reasonable schedule. The estimate accounts for the restructure of the FCS program and its increased scope,

the four-year extension to the product development schedule, the reintroduction of four systems that had been previously deferred, and the addition of a spin-out concept whereby mature FCS capabilities would be provided, as they become available, to current Army forces. Under the original estimate, the program planned to acquire enough FCS equipment for an average of two brigade combat teams per year and to equip all 15 by fiscal year 2020. Army officials told us that the current cost estimate incorporates the lengthened development schedule and a more realistic procurement plan under which the program will procure 1.5 brigade combat teams per year (versus two per year in the original cost estimate), reaching 15 complete brigade combat teams by fiscal year 2025. This cost estimate has also benefited from progress made in defining the FCS system of systems requirements.

Figure 5 compares the funding profiles for the original program and for the latest restructured program.

Figure 5: Comparison of Original Cost Estimate and Current Cost Estimate for FCS Program between Fiscal Years 2003 and 2026 (in millions of then-year dollars)



Source: U.S. Army (data); GAO (analysis and presentation).

The current FCS funding profile is lower than the original through fiscal year 2013, but is substantially higher than the original after fiscal year 2013. Stretching out FCS development by four years freed up about $9 billion in funding through fiscal year 2011 for allocation to other Army initiatives. Originally, FCS annual funding was not to exceed $10 billion in any one year. Now, the cost estimate is expected to exceed $10 billion in each of nine years. While it is a more accurate reflection of program costs than the original estimate, the latest estimate is still based on a low level of knowledge about whether FCS will work as intended. Also, the latest cost estimate has not yet been independently validated, as called for by DOD's acquisition policy. The Cost Analysis Improvement Group will not provide its updated independent estimate until spring 2006, for the planned Defense Acquisition Board review of the FCS program in May 2006.

The latest cost estimate does not include all the costs that will be needed to field FCS capabilities. For instance, the costs of the 52 essential complementary programs are separate, and some of those costs could be substantial. For example, the costs of the Joint Tactical Radio System Clusters 1 and 5 programs were expected to be about $32.6 billion (then-year dollars).[11] Some complementary programs, such as the Mid-Range Munition and Javelin Block II, are currently not funded for their full development. These and other unfunded programs would have to compete for already tight funding. Furthermore, program officials told us the procurement of the spin-outs from the FCS program to current Army forces is not yet entirely funded. Procuring the FCS items expected to be spun out to current forces is expected to cost about $19 billion, and the needed installation kits may add another $4 billion. Adding these items to the FCS cost estimate brings the total required investment from the Army to the $200 billion range.

The Army is planning to make substantial financial investments in the FCS program before key knowledge is gained on requirements, technologies, system designs, and system performance. Table 3 shows the annual and cumulative funding and the level of knowledge to be attained each fiscal year.

[11] The operational assessment of the Joint Tactical Radio System functionality has resulted in an ongoing program restructure, which could have an impact on the program's costs.

Table 3: Annual and Cumulative FCS Funding and Planned Events and Achievements

Fiscal year	Percentage of funding spent to date	Annual research, development, testing, and evaluation funding (in millions of dollars)	Cumulative research, development, testing, and evaluation funding (in millions of dollars)	Planned events and achievements
2003	0.5	158.9	158.9	Start of product development
2004	5.9	1,637.3	1,796.2	Program restructured
2005	15.5	2,929.9	4,726.1	System of Systems Functional Review; system of systems requirements stabilized; cost estimate updated
2006	26.7	3,398.4	8,124.5	Initial preliminary design review; initial system-level requirements
2007	38.7	3,669.4	11,793.9	
2008	50.7	3,655.6	15,449.5	Preliminary design review; most technologies reach TRL 6; initial critical design review; final system-level requirements
2009	61.9	3,419.2	18,868.7	All technologies reach TRL 6
2010	72.6	3,256.0	22,124.7	Critical design review; limited user test 2; some prototypes available
2011	81.8	2,799.9	24,924.6	Design readiness review; all system prototypes available
2012	88.2	1,952.3	26,876.9	Technologies reach full TRL 7 maturity; initial production decision; limited user test 3; initial system of systems demonstration
2013	92.9	1,410.8	28,287.7	
2014	96.7	1,167.3	29,455	Limited user test 4; full system of systems demonstration; fielding start brigade combat teams
2015	99.6	901.7	30,356.7	Initial operational capability
2016	100	108.3	30,465	Initial operational test and evaluation; full-rate production decision
2017				Full operational capability

Source: U.S. Army (data); GAO (analyst and presentation)

Through fiscal year 2006, about $8 billion will have been spent on FCS development efforts. However, many pre-development activities, such as requirements definition and technology development, were slated for this period. About one-half of FCS's development funding, or about $15 billion, will be spent by the time most critical technologies are mature to TRL 6 and the preliminary design review is conducted. About $22 billion, or over 70 percent of the total funding, will be spent by the expected time of the critical design review. Further, about 88 percent will have been spent before an initial demonstration of FCS capabilities is accomplished.

Army Has Taken Steps to Control FCS Program Costs

The Army has taken several steps to help manage the growing cost of FCS. Program officials told us they have budgeted for development risk by building a total of $5 billion into the FCS cost estimates to cover risk. Also, program officials have said that they will not exceed the $20.9 billion cost ceiling of the lead systems integrator's development contract, but may have to modify, reduce, or delete FCS requirements to stay within this target. For example, the Army has prioritized each of the FCS requirements. If one or more of the highest priority requirements ultimately cost more to develop than anticipated, the Army plans to modify, reduce, or delete a lower priority requirement. In addition to the ceiling on FCS development costs, the Army says it will focus on reducing the average unit production cost of the FCS brigade combat teams. To do this, the Army is evaluating and improving producibility of designs early in the program and has given the contractor incentives to reduce the unit costs.

The Army monitors the FCS program's development progress through its earned value management system. This is a tool by which the program manager can monitor the technical, schedule, and cost parameters of the contract. As the program proceeds, the Army and the lead systems integrator can determine the status of each portion and can take corrective actions as problems occur. While the earned value system currently shows that the program slightly exceeds schedule expectations and is below estimated cost against the restructured baseline, program officials said it is too early to broadly interpret these data in light of the recent rebaseline of the program. At this point, the Army believes that the data are not yet mature enough to develop trends and make predictions.

In addition, the Deputy Secretary of Defense, in early fiscal year 2006, asked each military service to provide additional adjustments to their projected budgets. The Army, in particular, was asked to decrease its budget by $11.7 billion from fiscal year 2007 to 2011. At this point, the FCS funding profile has not been affected.

Future Funding May Not Be Sufficient to Cover Projected FCS Procurement Costs

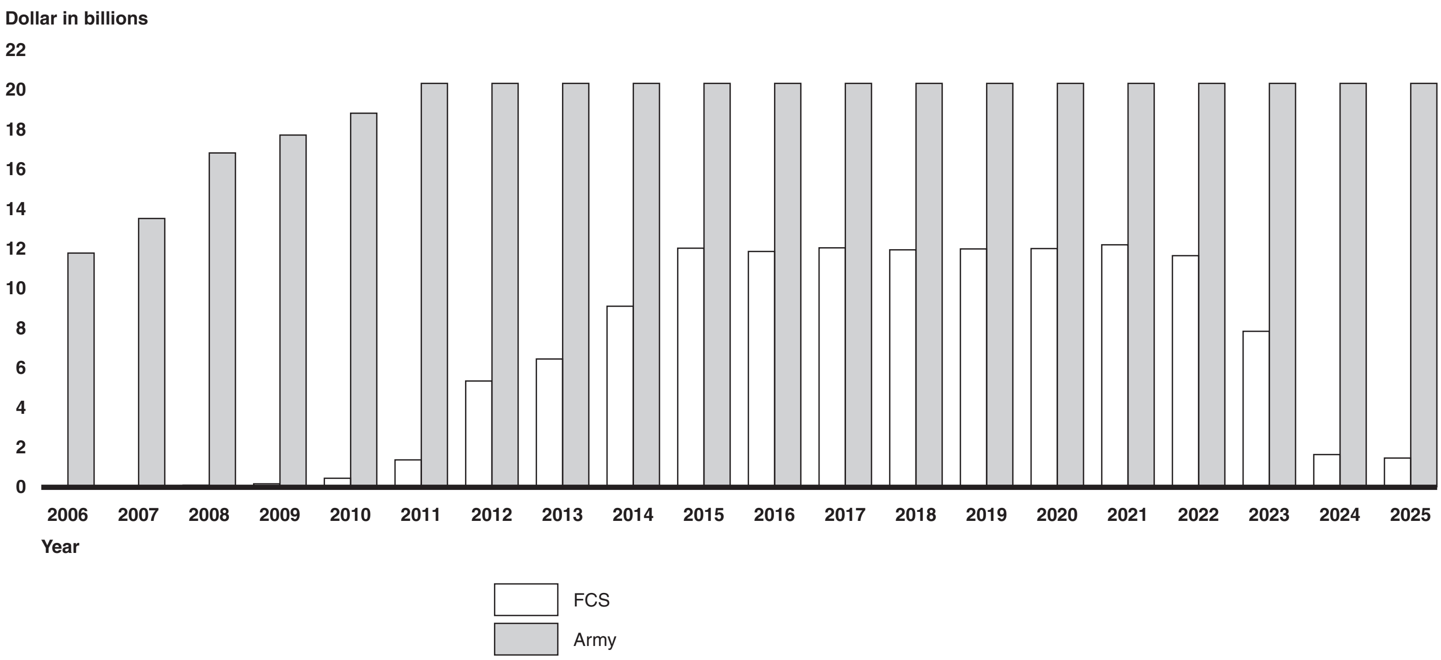
The affordability of the FCS program depends on several key assumptions. First, the program must proceed without exceeding its currently projected costs. Second, the Army's annual procurement budget is expected to grow, from about $11 billion (then-year dollars) in fiscal year 2006 to at least $20 billion in future years. The Army's projected budget also includes $5 billion per year from fiscal year 2007 through 2011 for its initiative to convert current Army forces to modular units. The Army is counting on its modularity initiative for brigade combat teams to be completed by fiscal

year 2014, just as FCS procurement dollars begin to ramp up. However, recent GAO work[12] has indicated that modularity efforts to date have exceeded original estimates and remain likely to further exceed current cost estimates. Army officials further told us that they expect to rely on supplemental funding for the war on terrorism and Operation Iraqi Freedom for the duration of those efforts plus two additional years. Within that supplemental funding, about $4 billion per year is projected to be needed to refurbish Army equipment used in Iraq and Afghanistan. The Army also assumes that (1) it will realize savings of about $5 billion per year from fiscal year 2005 through 2011 from business process engineering and (2) Congress will continue to provide additional annual funding of about $3 billion for higher Army troop levels.

Figure 6 compares the projected FCS budget with the funds the Army projects for its total procurement budget.

[12] GAO, *Force Structure: Actions Needed to Improve Estimates and Oversight of Costs for Transforming Army to a Modular Force.* GAO-05-926. (Washington, D.C.: September 29, 2005).

Figure 6: Comparison of FCS Budget with Total Army Procurement Budget (in billions of then-year dollars)



Source: U.S. Army (data); GAO (analysis and presentation).

The Army's annual procurement budget—not including funds specifically allocated for the modularity initiative—is expected to grow from about $11 billion in fiscal year 2006 to at least $20 billion by fiscal year 2011. Even if this optimistic projection comes to pass, FCS annual procurement costs will dominate the Army procurement funding. If the Army budget remains at fiscal year 2011 levels, FCS procurement will represent about 60-70 percent of Army procurement from fiscal years 2014 to 2022. With the remainder, the Army will have to address current force upgrades, including spin-outs from FCS, the procurement of FCS complementary programs, aviation procurement, trucks, ammunition, and other equipment. Further, FCS will have to compete for funding with other Army "big-ticket" items, such as missile defense systems and the future heavy lift helicopter.

The large annual procurement costs for FCS are expected to begin in fiscal year 2012, which is beyond the current Future Years Defense Plan period (fiscal years 2006-2011). This situation is typically called a funding bow wave. The term bow wave is used to describe a requirement for more funds just beyond the years covered in the current defense plan that are subject to funding constraints. As it prepares the next defense plan, the

Army will face the challenge of allocating sufficient funding to meet the increasing needs for FCS procurement in fiscal years 2012 and 2013. According to an Army official, if all the needed funding cannot be identified, the Army will consider reducing the FCS procurement rate or delaying or reducing items to be spun out to current Army forces. However, reducing the procurement rate would increase the FCS unit costs and extend the time needed to deploy FCS-equipped brigade combat teams.

Conclusions

The critical role played by U.S. ground combat forces is underscored today in Operation Iraqi Freedom and the global war of terrorism. That the Army should ensure its forces are well equipped with the capabilities they will need in the coming years is unquestioned. Moreover, the top-level goals the Army has set for its future force seem inarguable: to be as lethal and survivable as the current force, but significantly more sustainable and mobile. However, the Army's approach to meeting these needs—embodied in the FCS and complementary systems—does raise questions.

On the one hand, the FCS is the result of the Army leadership's taking a hard look at how it wants its forces to fight in the future. Army leadership has had the courage to break with tradition on FCS; it would have likely been much easier to win support for successor vehicles to the Abrams and Bradley. Perhaps the most compelling aspect of the FCS solution is the fact that the Army defined the larger context within which it wants its new assets and capabilities to work, including command and organizational changes. This holistic approach will facilitate designing individual systems to operate together in a way that has not been done in the past. In this sense, FCS is being designed to be much more than the sum of its individual parts.

On the other hand, FCS does not present a good business case for an acquisition program. It is necessary that a major new investment like FCS have a compelling, well-thought out concept, but this alone is not sufficient. FCS began product development prematurely in 2003, and today is a long way from having the level of knowledge it should have had before committing resources to a new product development effort. The elements of a sound business case—firm requirements, mature technologies, a knowledge-based acquisition strategy, a realistic cost estimate, and sufficient funding—are not present. FCS has all the indicators for risks that would be difficult to accept for any single system. They are even more daunting in the case of FCS not only because of their multiplicity, but because FCS represents a new concept of operations that is predicated on

technological breakthroughs. Thus, technical problems, which accompany immaturity, not only pose traditional risks to cost, schedule, and performance; they pose risks to the new fighting concepts envisioned by the Army.

The Army sees the foregoing as risk-averse thinking. The Army does not see immature technologies as an unacceptable risk, but as a "just in time" approach that is necessary to guard against technological obsolescence. The Army believes FCS technologies will mature predictably when needed and that they must have much latitude to make trade-offs across systems in case they do not mature. Similarly, the Army has set cost limitations for FCS and is prepared to make trade-offs in capability to offset future cost growth. Also, the Army is confident that advances in modeling and simulation reduce the reliance on physical testing to demonstrate performance.

It is possible that the Army's strategy for acquiring FCS could succeed as planned. But counting on it would require suspending credence in the lessons learned on other programs as well as the best practices of successful programs. Committing to the strategy also means setting aside DOD's acquisition policies—which espouse an evolutionary, knowledge-based approach—for an entire generation of Army acquisitions. The Army has made important progress on setting FCS system of systems requirements and making key decisions, such as vehicle weights. But its progress thus far seems to have done more to confirm risk than to have refuted it; setting system-level requirements and maturing technologies have proven difficult and are taking longer than planned.

In making decisions to commit additional resources to acquiring the capabilities represented by FCS, DOD must recognize the immaturity of the program and the amount of discovery that lies ahead. It is not a certainty that FCS will work and enable the concept of operations the Army envisions. A full commitment to the Army's strategy for acquiring FCS is not yet warranted because the Army has not demonstrated sufficient knowledge to provide confidence that it can deliver a fully capable FCS within projected costs and time frames. Based on the Army's plans, there should be sufficient progress on system-level requirements definition and technology development by the time of its preliminary design review in 2008 to realistically assess whether the program's goals are achievable and at what cost. As DOD proceeds with its decisions, it must preserve its ability to change course on acquiring FCS capabilities to guard against a situation in which FCS will have to be acquired at any cost. It must also be able to hold the Army accountable for delivering FCS

within budgeted resources. In this vein, options are available to frame FCS capabilities around a business case that comports with acquisition policies and best practices and to minimize risk within the current acquisition strategy. Alternatives to the current FCS acquisition strategy must also be kept viable in the event that desired capabilities prove unattainable.

Recommendations for Executive Action

We recommend that the Secretary of Defense limit DOD's commitment to the FCS product development phase and eventual production until a sound business case that is consistent with DOD acquisition policy and best practices can be clearly demonstrated.

We also recommend that the Secretary of Defense lay the groundwork for the Army's development of a sound FCS business case by tasking the spring 2006 Defense Acquisition Board to do the following:

- Revaluate the FCS business case—including requirements, technologies, complementary programs, acquisition strategy, cost, and funding availability—in light of its own acquisition policies. In its reevaluation, the board should (1) assess both the program's prospects for success and the consequences of not delivering desired capability within budgeted resources and (2) ensure that the Army has a disciplined way to measure and assess the cumulative effects of individual requirements, technology, design, and cost changes on the primary FCS characteristics of lethality, survivability, responsiveness, and sustainability.

- If the business case for FCS is found not to be executable, determine whether investments in FCS design- and production-related activities should be curbed until system-level requirements are firm and technologies are mature.

- If the deficiencies in the FCS business case are judged to be recoverable, establish the incremental markers that are needed to demonstrate that FCS is proceeding on a knowledge-based approach and to hold the Army accountable, through periodic reporting or other means, for achieving those markers. The markers should include, but not be limited to

  - the schedules for all critical technologies to realistically progress through TRL 7;
  - waypoints and criteria for reaching a set of system-level requirements that are both technically feasible and affordable;

- the schedule and funding availability for developing essential complementary programs;
- waypoints and criteria to be used to lead up to and complete the preliminary and critical design reviews;
- waypoints and criteria to be used to lead up to and complete testing of fully integrated prototypes of all FCS systems, including the network; and
- waypoints and criteria to be used to demonstrate that key production processes are in statistical control.

We recommend that the Secretary of Defense reassess the FCS cost estimate and funding availability based on the independent cost estimate and any program changes to improve its business case.

Finally, we recommend that the Secretary of Defense establish a milestone review by the Defense Acquisition Board following the Army's preliminary design review scheduled for 2008. This should be a go/no-go review of the FCS program that is based on (1) the program's ability to demonstrate whether it is meeting the knowledge markers outlined above at times consistent with DOD policy and best practices and (2) whether the funds can still be made available to afford its costs.

Matters for Congressional Consideration

Based on its response to our report, it does not appear that DOD plans to assess the FCS business case against best practices or its own policies. Nor has DOD agreed to hold a go/no-go milestone review in 2008 based on the preliminary design review. Congress will likely be asked to approve fiscal years 2008 and 2009 funding requests before the FCS business case is adequately demonstrated. In light of DOD's response, the Congress should consider directing the Secretary of Defense to:

- Report on the results of the May 2006 Defense Acquisition Board's review of the FCS program business case in the areas of requirements, technologies, acquisition strategy, cost, and funding.

- Direct DOD to conduct and report the results of a milestone review in 2008, following the preliminary design review, that will be a go/no-go review of the FCS program that is based on its demonstration of a sound business case.

The Congress should also consider restricting annual appropriations for fiscal years 2008 and 2009 for the FCS program until definitive progress in establishing a sound business case is demonstrated in terms of firm

requirements, mature technologies, a knowledge-based acquisition strategy, a realistic cost estimate, and sufficient funding. Importantly, the Army must provide sufficient evidence that FCS will work.

Agency Comments and Our Evaluation

DOD concurred with the intent of our recommendations but did not agree to limit its commitment to the FCS program or to take any action beyond what it had already planned to do. DOD stated it is committed to the Army's transformation and that effort, and in particular the FCS program, requires a disciplined, yet agile, acquisition construct. DOD added that the Defense Acquisition Executive has determined that the FCS program is based on a viable acquisition strategy. DOD stated that it would reevaluate the FCS acquisition strategy and reassess FCS cost estimates and funding in the spring 2006 Defense Acquisition Board review. DOD also noted that a Defense Acquisition Board review would be held for the timeframe (2008) of the FCS preliminary design review, but refrained from committing to making it a milestone decision review.

DOD's response to our draft report did not specifically address our findings on the FCS program's lack of a sound business case. DOD was also not specific about what criteria or standards for knowledge it would use in making its assessments, but referred to the incremental markers contained in the FCS acquisition strategy and system engineering plan. It is important that these markers reflect standards for knowledge that are consistent with best practices and DOD policy. Thus far, the FCS program has been judged by its own markers. As we have pointed out in this report, these markers have allowed FCS to be judged as acceptable despite its falling far short of the markers that represent best practices and DOD acquisition policy. For example, the low state of technology maturity has not prevented DOD from concluding that the FCS strategy is viable. Using the program's markers as a basis for future reviews raises the question of whether FCS will continue to be held to a lower standard than DOD policy. Over time, as the program's markers are adjusted in light of actual performance and more money is invested, it will become increasingly difficult for the Army and DOD to conclude that program progress is anything other than acceptable.

Regarding a commitment to a milestone review in 2008, we note that, in recognition of the fact that the FCS was allowed to proceed into Systems Development and Demonstration prematurely, DOD had directed a full milestone review update be held in November 2004. However, that review has not yet occurred and it now appears that it will not occur. Thus, there is no commitment by DOD to review the FCS business case (including all

elements in addition to the acquisition strategy), culminating in a go/no-go decision in 2008 based on the preliminary design review. The increased responsibility of making a declarative decision adds a higher level of discipline and accountability than a review implies. We maintain our position that such a decision is warranted.

It is important to note that Congress will continue to be asked to make funding commitments in advance of program events. Specifically, the budget request for fiscal year 2008, which will support the preliminary design review, will be presented to Congress for approval in January 2007. Conceivably, the request for the fiscal year 2009 budget, which will be presented in January 2008, will also precede the preliminary design review. Congress should safeguard itself against a situation in which budget decisions could preclude its ability to make adjustments to FCS as warranted by actual demonstrated performance against the business case. For example, the status of the FCS business case based on the knowledge demonstrated in the 2008 preliminary design review should be used to guide ensuing program activities and funding commitments. Accordingly, we have raised these issues as matters for congressional consideration.

We also received technical comments from DOD which have been addressed in the report, as appropriate.

We are sending copies of this report to the Secretary of Defense; the Secretary of the Army; and the Director, Office of Management and Budget. Copies will also be made available to others on request. Please contact me on (202) 512-4841 if you or your staff has any questions concerning this report. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Other contributors to this report were Assistant Director William R. Graveline, Robert L. Ackley, Lily J. Chin, Noah B. Bleicher, Marcus C. Ferguson, Michael J. Hesse, Guisseli Reyes, Lisa R. Simon, John P. Swain, and Carrie R. Wilson.

Paul L. Francis
Director
Acquisition and Sourcing Management

List of Committees:

The Honorable John W. Warner
Chairman
The Honorable Carl Levin
Ranking Minority Member
Committee on Armed Services
United States Senate

The Honorable Ted Stevens
Chairman
The Honorable Daniel K. Inouye
Ranking Minority Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Duncan L. Hunter
Chairman
The Honorable Ike Skelton
Ranking Minority Member
Committee on Armed Services
House of Representatives

The Honorable C. W. Bill Young
Chairman
The Honorable John P. Murtha
Ranking Minority Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Scope and Methodology

To develop the information on the Future Combat System program's progress toward meeting established goals, the contribution of critical technologies and complementary systems, and the estimates of cost and affordability, we interviewed officials of the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics); the Army G-8; the Office of the Under Secretary of Defense (Comptroller); the Secretary of Defense's Cost Analysis Improvement Group; the Director of Operational Test and Evaluation; the Assistant Secretary of the Army (Acquisition, Logistics, and Technology); the Army's Training and Doctrine Command; Surface Deployment and Distribution Command; the Program Manager for the Future Combat System (Brigade Combat Team); the Future Combat System Lead Systems Integrator; and LSI One Team contractors. We reviewed, among other documents, the Future Combat System's Operational Requirements Document, the Acquisition Strategy Report, the Baseline Cost Report, the Critical Technology Assessment and Technology Risk Mitigation Plans, and the Integrated Master Schedule. We attended the FCS System of Systems Functional Review, In-Process Reviews, Board of Directors Reviews, and multiple system demonstrations. In our assessment of the FCS, we used the knowledge-based acquisition practices drawn from our large body of past work as well as DOD's acquisition policy and the experiences of other programs.

We discussed the issues presented in this report with officials from the Army and the Secretary of Defense, and made several changes as a result. We performed our review from June 2005 to March 2006 in accordance with generally accepted auditing standards.

Appendix II: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION
TECHNOLOGY
AND LOGISTICS

MAR 0 3 2006

Mr. Paul L. Francis
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
Washington, D.C. 20548

Dear Mr. Francis:

This is the Department of Defense (DoD) response to the GAO draft report GAO-06-367, "Defense Acquisitions: Improved Business Case is Needed for Future Combat Systems' Successful Outcome," dated February 6, 2006 (GAO Code 120456).

The report recommends that the Secretary of Defense withhold full commitment to Future Combat Systems (FCS) until a sound business case is demonstrated. It further recommends the Defense Acquisition Board reevaluate the FCS business case and establish incremental knowledge markers for assessing FCS progress.

The Department concurs with the intent of all GAO recommendations. The Army's transformation effort, and in particular the FCS program, requires a disciplined, yet agile, acquisition construct. The strategy to develop and acquire FCS represents the Department's business case and includes periodic acquisition reviews by the Department, in addition to the milestone reviews called for by DoD acquisition policy. The acquisition has been restructured to spin-out mature FCS capabilities to the current force, with each spin-out having decision points consistent with DoD acquisition policy. Detailed comments on the report are enclosed.

Sincerely,

Mark D. Schaeffer
Acting Director
Defense Systems

Enclosure:
As stated

GAO DRAFT REPORT DATED FEBRUARY 6, 2006
GAO-06-367 (GAO CODE 120456)

"DEFENSE ACQUISITIONS: IMPROVED BUSINESS CASE IS NEEDED for FUTURE COMBAT SYSTEMS' SUCCESSFUL OUTCOME"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense withhold full commitment to the Future Combat System (FCS) product development phase and eventual production until a sound business case that is consistent with DOD acquisition policy and best practices can be clearly demonstrated. (p. 40/GAO Draft Report)

DOD RESPONSE: Partially Concur. The Department is committed to the Army's transformation efforts for expeditious and effective integration of emerging capabilities into the current force, while continuing to move toward the future land combat vision. This requires a disciplined, yet agile, acquisition construct. The FCS acquisition is the Army's principal modernization effort. The FCS acquisition strategy, or business case in the GAO vernacular, includes regular acquisition reviews, in addition to the milestone reviews called for by DoD acquisition policy. The acquisition has been restructured to spin-out mature FCS capabilities to the current force, with each spin-out having decision points consistent with DoD acquisition policy. The periodic reviews of the FCS acquisition, by the Defense Acquisition Board and the Joint Requirements Oversight Council offers opportunities to inform and alter Department acquisition and budget decisions and prioritize program efforts.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense lay the groundwork for a sound FCS business case by tasking the spring 2006 Defense Acquisition Board to revaluate the FCS business case-including requirements, technologies, complementary programs, acquisition strategy, cost, and funding availability-in light of its own acquisition policies. In its reevaluation, the board should (1) assess both the program's prospects for success and the consequences of not delivering desired capability within budgeted resources and (2) ensure that the Army has a disciplined way to measure and assess the cumulative effects of individual requirements, technology, design, and cost changes on the primary FCS characteristics of lethality, survivability, responsiveness, and sustainability. (p. 40/GAO Draft Report)

DOD RESPONSE: Concur. The FCS acquisition review in spring 2006 will reevaluate the FCS acquisition strategy.

RECOMMENDATION 3: The GAO recommended that if the business case is found not to be executable, that the Secretary of Defense lay the groundwork for a sound FCS business case by tasking the spring 2006 Defense Acquisition Board to determine whether investments in FCS design- and production-related activities should be curbed until system level requirements are firm and technologies are mature. (p. 40/GAO Draft Report)

DOD RESPONSE: Concur. The spring 2006 FCS review will inform acquisition decisions and Department budget planning.

RECOMMENDATION 4: The GAO recommended that if the deficiencies in the FCS business case are judged to be recoverable, that the Secretary of Defense lay the groundwork for a sound FCS business case by tasking the spring 2006 Defense Acquisition Board to establish the incremental markers that are needed to demonstrate that FCS is proceeding on a knowledge–based approach and to hold the Army accountable, through periodic reporting or other means, for achieving those markers. (p. 40/GAO Draft Report)

DOD RESPONSE: Concur. The Defense Acquisition Executive has determined that the FCS program is based on a viable acquisition strategy. The program will be periodically reviewed to assess the program's progress. Expectations for incremental markers to demonstrate FCS progress will continue to be established and defined in the FCS acquisition strategy and the FCS System Engineering Plan and progress towards those markers regularly reviewed.

RECOMMENDATION 5: The GAO recommended that the Secretary of Defense reassess the FCS cost estimate and funding availability based on the independent cost estimate and any program changes to improve its business case. (p. 41/GAO Draft Report)

DOD RESPONSE: Concur. The FCS acquisition, to include program cost estimates and funding, will be reviewed in the spring of 2006 to support budget planning and programming.

RECOMMENDATION 6: The GAO recommended that the Secretary of Defense establish a milestone review by the Defense Acquisition Board following the Army's preliminary design review scheduled for 2008. This should be a go/no-go review of the FCS program that is based on (1) the program's ability to demonstrate whether it is meeting the knowledge markers outlined above at times consistent with DOD policy and best practices; and (2) whether the funds can still be made available to afford its costs. (p. 41/GAO Draft Report)

DOD RESPONSE: Partially concur. An FCS acquisition review, while not a milestone review, is planned for the timeframe of the FCS preliminary design review.

Appendix III: Critical Technologies' Current Status and Projections for Reaching Technology Readiness Level 6 (TRL 6)

FCS Critical Technologies and Associated Key Performance Parameters			TRL Ratings	TRL 6 Projections
Network ready		**Software programmable radio**		
	1	JTRS Cluster 1	5	2007
	2	JTRS Cluster 5	5	2007
	3	WIN-T	5	2007
		Interface and information exchange		
	4	Army, joint, multinational Interface	4	2008
	5	WIN-T strategic communication	4	2008
Networked battle command		**Security systems and algorithms**		
	6	Cross domain guarding solution	4	2008
	7	Intrusion detection—Internet Protocol Network	4	2008
	8	Intrusion detection—Waveform	4	2008
	9	**Mobile ad hoc networking protocols**	5	2007
	10	**Quality of service algorithms**	5	2007
	11	**Unmanned systems relay**	5	2006
		Wideband Waveforms		
	12	Wideband waveform—JTRS	5	2007
	13	Wideband waveform—Soldier Radio Waveform	4	2007
	14	**Advanced man-machine interfaces**	6	Not applicable
	15	**Multi-spectral sensors and seekers**	6	Not applicable
	16	**Decision aids/intelligent agents**	6	Not applicable
		Combat identification		
	17	Air (rotary wing/Unmanned Aerial Vehicle)—to—ground	6	Not applicable
	18	Air (fixed wing)—to—ground (interim/robust solutions)	Not rated	Not applicable
	19	Ground—to—air	Not rated	Not applicable
	20	Ground—to—ground (mounted)	6	Not applicable
	21	Ground—to—soldier	Not rated	Not applicable
	22	**Rapid battlespace deconfliction**	5	2008
		Sensor/data fusion and data compression algorithms		
	23	Distributed fusion management	4	2007
	24	Level 1 fusion engine	6	Not applicable
	25	Data compression algorithms	6	Not applicable
Networked lethality	26	**Dynamic sensor—shooter pairing algorithms and fire control**	6	Not applicable
		Line-of-Sight/Beyond-Line-of-Sight/Non-Line-of-Sight Precision Munitions Terminal Guidance		
	27	Precision Guided Mortar Munitions precision munitions, terminal guidance	5	2007

FCS Critical Technologies and Associated Key Performance Parameters			TRL Ratings	TRL 6 Projections
	28	Mid-Range-Munitions precision munitions, terminal guidance	5	2007
	29	Excalibur precision munitions, terminal guidance	6	Not applicable
	30	Non-Line-of-Sight Launch System, terminal guidance	6	Not applicable
		Aided/automatic target recognition		
	31	Aided target recognition for reconnaissance, surveillance, and target acquisition	5	2007
	32	Non-Line-of-Sight Launch System aided target recognition for seekers	6	Not applicable
	33	**Recoil management and lightweight components**	6	Not applicable
	34	**Distributed collaboration of manned/unmanned platforms**	5	2006
	35	**Rapid battle damage assessment**	Not rated	Not applicable
Transportability		**High-power density/fuel-efficient propulsion**		
	36	High-power density engine	5	2007
	37	Fuel-efficient hybrid-electric engine	6	Not applicable
Sustainability/ reliability	38	**Embedded predictive logistics sensors and algorithms**	5	2009
	39	**Water generation and purification**	Not rated	Not applicable
Training	40	**Computer generated forces**	6	Not applicable
	41	**Tactical engagement simulation**	4	2008
Survivability		**Active Protection System**		
	42	Active Protection System	5	2008
	43	Threat Warning System	4-5	2009
	44	**Signature management**	5-6	2006
	45	**Lightweight hull and vehicle armor**	5	2008
	46	**Health monitoring and casualty care interventions**	6	Not applicable
	47	**Power distribution and control**	5	2006
		Advanced countermine technology		
	48	Mine detection	6	Not applicable
	49	Mine neutralization	6	Not applicable
	50	Efficient resource allocation	6	Not applicable
	51	Protection	4	2008
	52	**High-density packaged power**	5	2008
		Class 1 Unmanned Aerial Vehicle propulsion technology		
	53	Ducted fan	4	2006
	54	Lightweight heavy fuel engine	4	2007

Source: Technology Readiness Assessment Update, Office of the Deputy Assistant Secretary of the Army for Research and Technology, April 2005 (data); GAO (analysis and presentation).

Appendix IV: Technology Readiness Levels

Technology Readiness Level	Description	Hardware and Software	Demonstration Environment
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties	None (paper studies and analysis)	None
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis)	None
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of non-scale individual components (pieces of subsystem).	Lab
4. Component and/or breadboard. Validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.	Low-fidelity breadboard. Integration of non-scale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab
5. Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory Integration of components.	High-fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size, weight, materials, etc.). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	Prototype—Should be very close to form, fit, and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.

Technology Readiness Level	Description	Hardware and Software	Demonstration Environment
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit, and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative operational environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and “flight qualified” through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight-qualified hardware	Developmental test and evaluation in the actual system application
9. Actual system “flight proven” through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last “bug fixing” aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Operational test and evaluation in operational mission conditions

Source: GAO and its analysis of National Aeronautics and Space Administration data.

Related GAO Products

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